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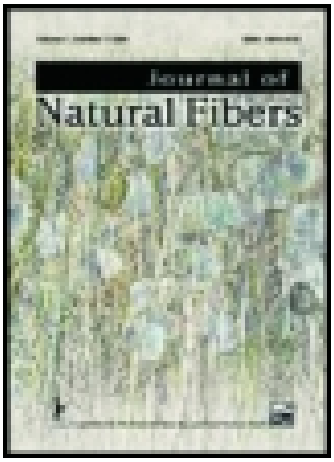

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Dyeing of Jute Fabric Using Indigosol Dyes

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Bleached jute fabric has been dyed with three indigosol dyes, namely Indigosol Violet I4R, Indigosol Golden Yellow IGK, and Indigosol Blue O4B, having different sensitivity to oxidation. Development stage (i.e., oxidation, neutralization, and soaping of the dyed fabric) plays the most important role for dyeing of jute fabric with indigosol dyes. Concentrations of chemicals in different processing steps such as sodium nitrite in the dye bath, sulphuric acid in the developing bath, sodium carbonate in the neutralization bath, and non-ionic surface active agent in the soaping bath have been optimized. Color yield and fastness properties are found to be better if dyeing and developing steps are carried out separately. Retention of tensile strength of indigosol-dyed jute fabric is sufficient enough for its further use in making diversified and value-added products. Moreover, the handle property of the indigosol-dyed jute fabric is found to be good.

KEYWORDS bleaching, bending length, color yield, indigosol dyes, jute fabric, tensile strength, wash fastness

INTRODUCTION

Jute, cellulose-rich lignocellulosic natural fiber, has occupied a strong position in the production of diversified and value-added products such as upholstery,

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furnishing textiles, curtains, wall hangings, and outer garments, etc., apart from its traditional dominant position in packaging. These entire products need an attractive look and feel depending on the end use and value of the end product. Jute fabric is made attractive either by dyeing or printing methods. Several processes of dyeing of jute fabric using different dyes (Chattopadhyay et al. 2006) have been developed to produce colored jute fabric having a wide range of wash and light fastness. Generally, jute fabric to be used for outdoor application such as curtains, car seat covers, tent cloth, outer garments, etc., requires high wash as well as light fastness properties whereas indoor applications such as sofa covers, table cloth, etc., require high wash-fastness properties.

Indigosol dyes produce excellent wash and light fastness properties particularly in pale shades. The good leveling and penetration quality of these dyes on tightly twisted yarn, even in light shades, is attributed to their moderate affinity and slow exhaustion. As the use of dyed jute fabric is widening, it is high time to develop a standard process of dyeing of this lignocellulosic fiber using indigosol dyes. So, a systematic study has been made to develop the dyeing process on jute fabric using indigosol dyes.

In the present work three different indigosol dyes (Indigosol Violet I4R, Indigosol Golden Yellow IGK, and Indigosol Blue O4B), having different sensitivity to oxidation, were applied on a bleached jute fabric separately by following a double-step method and the single-step method. A comparative study was also done. The complex structure and chemical composition of jute (Macmillan et al. 1954) makes chemical processing of jute very critical. So, apart from the evaluation of dyeability characteristics of all the dyed fabrics, their physical characteristics were also evaluated in this study.

MATERIALS AND METHODS

Material

Substrate

A plain weave grey jute fabric with the following specifications was used.

- Warp: 60 ends/dm (count, 260 tex)
- Weft: 51 ends/dm (count, 268 tex)
- Fabric mass: 260 g/m^2 (at 65% RH and 27°C)

Chemicals

The following chemicals of analytical grade were used in the experiment: hydrogen peroxide, trisodium phosphate, sodium hydroxide, sodium carbonate, sodium silicate, sodium nitrite, sulphuric acid, nonionic detergent (Ultravon JU), and glaubers' salt.

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Dyestuffs

Three indigosol dyes of different sensitivity to oxidation were used for dyeing the jute fabric. Details of the indigosol dyes used are tabulated in Table 1.

Methods

Bleaching

Bleaching of grey jute fabric was done in a closed vessel for 90 min at 80°C– 85°C and the material-to-liquor ratio was kept at 1:20 with hydrogen peroxide (2 vol), trisodium phosphate (5 g/L), Ultravon JU (2 mL/L), sodium hydroxide (1 g/L), sodium silicate (10 g/L). The pH of the bath was maintained at 10. After bleaching, the fabrics were washed thoroughly in cold water, neutralized with acetic acid (2 mL/L), washed again in cold water, and finally dried.

Dyeing

Dyeing of jute fabric with indigosol dyes involves different step-like dissolution, exhaustion, developing, neutralization, soaping, etc. Exhaustion and development of the dye may be carried out by double-step or single-step methods. Bleaching and dyeing of jute fabric samples were carried out by using Laboratory Scale Jigger Machine.

Double step method. For dissolution, hot water was poured over the dye with stirring. A little soda ash equal to the weight of the dye was added to the solution for facilitating dissolution. Glaubers' salt (30 g/L), sodium nitrite (0.25, 0.5, 1.0, 2.0 g/L), soda ash (0.5 g/L) were added to the dye bath. The material was entered into the bath, temperature was raised to 40°C, and the material was run for 60 min with continuous movement using a material to liquor ratio of 1:20. After dyeing, the fabric sample was taken out, squeezed, and without rinsing dipped in the developing bath containing sulphuric acid (1, 2, 3 g/L) for regeneration of the dye. The sample was treated for 30 min at ambient temperature and then neutralized in a bath

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TABLE 1 Details About Indigosol Dyes

Commercial name of the dye	Sensitivity to oxidation	CI generic number	CI constitution number
Indigosol Violet I4R	High	Solubilized Vat Violet 1	60011
Indigosol Golden Yellow IGK	Medium	Solubilized Vat Yellow 4	59101
Indigosol Blue O4B	Low	Solubilized Vat Blue 5	73066

containing soda ash (0.5, 1.0, 2.0 g/L) at a temperature of 50°C for 15 min. Finally the fabric was rinsed, soaped at boil, washed, and dried.

Single step method. For dissolution, hot water was poured over the dye with stirring. A little soda ash equal to the weight of the dye was added to the solution for facilitating dissolution. Glaubers' salt (30 g/L), sodium nitrite (0.25, 0.5, 1.0, 2.0 g/L), and soda ash (0.5 g/L) were added to the dye bath. The material was entered into the bath, the temperature was raised to 40°C, and the material was run for 60 min with continuous movement using a material to liquor ratio of 1:20. Then sulphuric acid (2 g/L) was added to the same bath for developing and the treatment continued for 30 min at ambient temperature. The sample was neutralized in a bath containing soda ash (2.0 g/L) at a temperature of 50°C for 15 min with a material to liquor ratio at 1:20. Finally the fabric was rinsed, soaped at boil, washed, and dried.

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Determination of the Physicochemical Property

Whiteness index, yellowness index and brightness index

The whiteness index on the Hunter scale, yellowness index on the ASTM D 1925 scale, and brightness index on the Tappi 45 scale of grey and bleached jute fabric samples were measured by the Spectrascan 5100 computerized color-matching system with the relevant software.

Color strength

The relative color strength (in terms of K/S value) of indigosol-dyed jute fabrics were measured (Chattopadhyay et al. 2004) by the light reflectance technique using the Kubelka-Munk equation:

$$K/S = (1-R)^2/2R$$

Where, K is the coefficient of absorption, S the coefficient of scattering, and R the reflectance. The R of dyed fabrics was measured on a Spectrascan 5100 computerized color-matching system.

Wash fastness

All the indigosol-dyed fabric samples were subjected to a wash-fastness test in a Launder-o-Meter as per specified in IS: 3361-1979 (Bureau of Indian Standards 1982a). The wash-fastness rating of all the dyed fabric samples was evaluated with a computerized color-matching system.

Absorbency

Absorbency of grey and bleached jute fabric samples was determined as per specified in IS: 2369-1967 (Bureau of Indian Standards 1982b)

Bending length

Bending length is a measure of stiffness that determines the draping quality and handle property of the fabric. Bending length of grey, bleached, and all the indigosol-dyed jute fabric samples were determined as per specified in IS: 6490-1971 (Bureau of Indian Standards 1982c) using stiffness tester.

Tensile properties

The HEICO tensile-testing machine was used for the evaluation of tensile properties of jute fabric samples using the 1-in cut strip test method (ASTM D 1682-1975).

A jute fabric specimen was gripped between two pneumatic jaws of the tensile tester (gauge length 7.5 cm) and a continual increasing load was applied longitudinally to the fabric specimen by moving the upper jaw at an X-head speed of 5 cm/min until the fabric specimen breaks. Breaking load and elongation were determined. Tenacity and extension (%) at break were then calculated as follows:

$$\text{Tenacity } (\text{cN/tex}) = \frac{\text{L}}{\text{W} \times \text{gsm}}$$

Where L is the breaking load in cN, W is the test width in meter and gsm is the areal density of fabric in g/cm^2

$$\text{Extension } (\%) = \frac{\text{Elongation } (\text{mm})}{\text{Original length } (\text{mm})} \times 100$$

An average of 10 readings both in warp and weft direction was taken to represent the tensile properties of the fabric.

RESULTS AND DISCUSSION

Vat dyes are generally converted into their soluble forms, which are substantive to textile fibers by conventional reduction and solubilization process. But vat dyes are also available in soluble form and, having affinity for textile

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fibers, named as indigosol dyes. Chemically they are sulphuric esters of leuco vat dyes and may be called leuco esters. After application of solubilized vat dyes on textile materials, they are converted into original vat dyes from which they have been manufactured. General properties of the indigosol dyes are as follows:

- Solubility in water
- Sensitivity to light
- Substantivity to textile fibers
- Sensitivity to oxidation and development
- Dyes have maximum affinity at a particular temperature

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Dyeing of indigosol dyes involves two steps:exhaustion of dyes onto textile material by the manipulation of the temperature of the dye bath and by the addition of salt; and regeneration of vat dye (i.e., development), which is carried out using a solution of nitrous acid formed from sodium nitrite and sulphuric acid. To avoid the nitrous fumes, which are produced when sodium nitrite is added to sulphuric acid, in the present study sodium nitrite was added to the dye bath and then the dye was developed in the sulphuric acid bath. Sodium nitrite, being an electrolyte, also helps in the exhaustion of the dye bath.

Jute is a biodegradable and natural lignocellulosic fiber. So, apart from cellulose, it contains hemicellulose, lignin, wax, fats, and different added and natural contaminants. Pretreatment of the fabric by alkaline hydrogen peroxide bleaching (Chattopadhyay et al. 2006 [Bioresource Technology]) produces clean fabric with improved optical and absorbency properties, which are shown in Table 2.

Bleached jute fabric was dyed with Indigosol I4R for optimization of process parameters. It was found that oxidation, neutralization, and soaping of the dyed fabric play the most important roles in dyeing jute fabric with indigosol dyes. Study has been done on the variation of concentration of sodium nitrite (oxidizing agent), neutralization condition, and soaping condition. Analysis of Table 3 reveals that the addition of 0.5 g/L sodium nitrite in the dye bath carries sufficient amounts of oxidizing agent to the subsequent developing bath to produce actual hue of the dye, which is confirmed by its λ_{max} value of 540 nm; otherwise it is 530 nm, which is overoxidized. Similarly, the dose of sulphuric acid in the developing bath has been varied

TABLE 2 Optical and Absorbency Property of Grey and Bleached Jute Fabrics

Samples	Whiteness index (HUNTER)	Yellowness index (ASTM D 1925)	Brightness index (TAPPI 452)	Absorbency (seconds)
Grey	51.73	48.15	21.15	900
Bleached	79.25	22.88	57.39	4

TABLE 3 Effect of Dyeing Parameters on Hue, Colour Yield, λ_{max} Value and Wash Fastness of Indigosol (Indigosol Violet I 4R) Dyed Jute Fabric

Parameters	λ_{max}(nm)	K/S value	Wash fastness
X = 4 g/L, Y = 2 g/L, Z = 2 g/L	530	7.17	2–3
X = 1 g/L, Y = 2 g/L, Z = 2 g/L	530	7.12	3
X = 0.5 g/L, Y = 2 g/L, Z = 2 g/L	540	7.83	4
X = 0.5 g/L, Y = 2 g/L, Z = 1 g/L	540	6.98	4
X = 0.5 g/L, Y = 2 g/L, Z = 0.5 g/L	540	6.27	3
X = 0.5 g/L, Y = 3 g/L, Z = 2 g/L	540	6.48	3
X = 0.5 g/L, Y = 1 g/L, Z = 2 g/L	540	6.03	3

X = Sodium nitrite, added in the dye bath.
Y = Sulphuric acid, added in the developing bath.
Z = Sodium carbonate, added in the neutralizing bath.

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and 2 g/L concentration seems to produce good wash fastness as well as perfect hue. By following this method, the oxidation process is made very specific as it takes place only where sodium nitrite is present, resulting in proper oxidation of the dye. So, there is no overoxidation of the dye and there is no reaction with other noncellulosic constituents present in composite jute fiber. It was also found that the neutralization of developed dyed jute fabric using 2 g/L sodium carbonate produces the best color yield. Soaping of dyed fabric with 0.5 g/L non-ionic detergent at boil is sufficient for removing any unfixed dye.

Various shades (0.5%, 1.0%, 2.0%, 3.0%, and 4.0%) were produced using indigosol dyes, namely Indigosol Violet I4R on bleached jute fabric using optimum condition, and their color yield as well as fastness properties were studied. The results have been tabulated in Table 4. Color yield was found to be proportionate with the concentration of dye used and wash fastness is good in all the cases. A further study on dyeing and developing of bleached jute fabric in the same bath was done using indigosol dye. It was found that the concentration of sodium nitrite needed to be reduced to

TABLE 4 Effect of Dye Concentration and Method of Dyeing on Optical Properties of Indigosol Violet I 4R Dyed Jute Fabric

Method of dyeing	Dye concentration (%, on the weight of the fabric))	λ_{max}(nm)	K/S value	Wash fastness
Conventional two bath	0.5	540	3.01	4
	1.0	540	4.63	4
	2.0	540	7.83	4
	3.0	540	9.23	4
	4.0	540	10.97	4
Modified single bath	2.0 (0.5 g/L sodium nitrite)	530	6.95	3
	2.0 (0.25 g/L sodium nitrite)	540	6.78	3

half compared to the normal quantity to produce the actual hue of the dye, which is confirmed by its λ_{max} value of 540 nm. Wash fastness is slightly lower in this case.

Using the optimized parameters and the two-step dyeing method, Indigosol Golden Yellow IGK was applied on bleached jute fabric using three different shades. The results of evaluation of optical properties were tabulated in Table 5.

It is found that the colors build up with an increase in the concentration of dye in the dye bath and wash-fastness values are very good in all the cases, which is expected from indigosol dye. A deep shade can be obtained by using 2% shade and λ max value of the dye is 470 nm. In this case the concentration of sodium nitrite needed to produce maximum color yield was found to be 0.75 g/L.

Another indigosol dye, Indigosol Blue O4B, was used to dye the bleached jute fabric. This dye is difficult to oxidize. So, a different concentration of oxidizing agents was used to standardize the process and it was found that 1g/L sodium nitrite in the dye bath is sufficient for oxidation of the dye in the subsequent sulphuric acid bath. Three different shades (1%, 2%, and 3%) were produced on bleached fabric. Color yield and wash-fastness properties of all the dyed fabrics were evaluated and tabulated in Table 6. In this case the 2% shade also produced good color buildup. Wash-fastness values of the samples were found to be 3–4, which is considered to be a good wash-fastness value. λmax value of the dye is 590.

For dyeing of jute fabric, concentration of chemicals in different processing steps like sodium nitrite in the dye bath, sulphuric acid in the developing bath, sodium carbonate in the neutralization bath, and nonionic surface active agent in the soaping bath have been optimized for each type of indigosol dyes, which are tabulated in Table 7.

TABLE 5 Optical Properties of Indigosol Golden Yellow IGK Dyed Jute Fabric

Dye concentration (%, on the weight of the fabric))	λ_{max}(nm)	K/S value	Colour strength (%)	Wash fastness
1	470	3.81	100.00	4
2	470	5.27	138.03	4
3	470	5.98	156.75	4

TABLE 6 Optical Properties of Indigosol Blue O4B Dyed Jute Fabric

Dye concentration (%, on the weight of the fabric))	λ_{max}(nm)	K/S value	Colour strength (%)	Wash fastness
1	590	3.93	100.00	3–4
2	590	6.69	170.00	3–4
3	590	7.56	192.00	3–4

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TABLE 7 Optimised Conditions of Dyeing Jute Fabric Using Different Indigosol Dyes

Commercial name of the dye	Sensitivity to oxidation	Optimized concentrations (g/L)			
		Sodium nitrite	Sulphuric acid	Sodium carbonate	Nonionic detergent
Indigosol Violet I4R	High	0.50	2.00	2.00	0.50
Indigosol Yellow IGK	Medium	0.75	2.00	2.00	0.50
Indigosol Blue O4B	Low	1.00	2.00	2.00	0.50

TABLE 8 Tensile and Handle Properties of Pretreated and Dyed Jute Fabrics

Jute fabric	Warp		Weft		Bending length (cm)	
	Tensile Strength (cN/tex)	Extension at break (%)	Tensile Strength (cN/tex)	Extension at break (%)	Warp	Weft
Grey	4.56	6.12	4.82	5.98	4.95	4.88
Bleached	3.86	12.16	4.18	10.68	3.7	3.85
Indigosol Blue O4B	3.55	9.6	3.67	8.98	3.5	3.4
Indigosol Violet I4R	3.64	9.8	3.73	9.61	3.26	3.33
Indigosol Yellow IGK	3.46	8.8	3.65	8.61	3.3	3.2

Grey, bleached, and indigosol dyed jute fabrics were evaluated for tensile and handle properties. Tensile strength was determined by using a HEICO tensile testing machine and bending length was determined by a SASMIRA Bending length tester. All the results are tabulated in Table 8.

With respect to tensile strength, analysis of Table 8 reveals that there is a drop in tensile strength after bleaching both in warp and weft direction. The loss is due to removal of hemicellulose and a little lignin (Pan et al. 2003). There is no further loss of strength after dyeing. The retention of strength is sufficient for its further use in making value-added diversified products. All the processed fabrics show more extension at maximum load compared to grey jute fabric. This may be because of stress relaxation during chemical processes. It was found that the fabric becomes progressively softer after each chemical process and as the dyed fabric is produced after undergoing several chemical processes; it shows the minimum bending length due to cumulative effect. As a result, dyed fabric shows very good handling properties.

CONCLUSIONS

- Bleached jute fabric can be dyed with different indigosol dyes to produce brightly colored jute fabric with good wash-fastness properties.
- The addition of an oxidizing agent (i.e., sodium nitrite in the dye bath) has proved a better alternative than the addition to the developing bath.

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Sodium nitrite, being an electrolyte, also acts as an exhausting agent if added in the dye bath.

- Color yield and wash fastness of dyed jute fabric is better if the dyeing and development stages are separated.
- Development stage (i.e., oxidation, neutralization, and soaping of the dyed fabric) play the most important role for the dyeing of jute fabric using indigosol dyes.
- There is a little drop in tensile strength of the indigosol dyed jute fabric compared to bleached jute fabric and can be conveniently used for producing value-added and diversified jute products.
- The indigosol-dyed jute fabric shows lower bending length and high extension at break. Hence the dyed jute fabric possesses good handling properties.

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